

SECTION 31 50 00

EXCAVATION SUPPORT AND PROTECTION

PART 1 –GENERAL

1.01 SECTION INCLUDES

- A. Detection of movement
- B. Soldier piles and lagging
- C. Sheet piling
- D. Slurry walls
- E. Bracing and tiebacks
- F. Soil anchors
- G. Soil nailing
- H. Secant walls
- I. Soil mix walls
- J. Removal of excavation support systems
- K. Restoration

1.02 RELATED SECTIONS

- A. Shoring and underpinning for safeguarding structures are specified in Section 31 40 00, Shoring and Underpinning.
- B. Instrumentation for monitoring earth and structure movements, as well as subsurface water levels, is specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
- C. Excavation and other earthwork operations are specified in Section 31 00 00, Earthwork.
- D. Trenching for utilities is specified in Section 33 05 28, Trenching and Backfilling for Utilities.
- E. Coordinate the work of this Section with the work of Section 31 23 19, Dewatering, and Section 31 40 00, Shoring and Underpinning.

1.03 MEASUREMENT AND PAYMENT

- A. Measurement: Excavation Support Systems will be measured for payment by the lump-sum method, acceptably constructed, maintained, and removed.
- B. Payment: Excavation Support Systems will be paid for at the Contract lump-sum price, as indicated in the Bid Schedule of the Bid Form.

1.04 REFERENCES

- A. American Society of Civil Engineers (ASCE):
 - 1. ASCE 37 Design Loads on Structures during Construction
- B. American Society for Testing and Materials (ASTM):
 - 1. ASTM A36 Specification for Structural Steel
 - 2. ASTM A328 Specification for Steel Sheet Piling
 - 3. ASTM A416 Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete
 - 4. ASTM A563 Specification for Carbon and Alloy Steel Nuts
 - 5. ASTM A586 Standard Specification for Metallic-Coated Parallel and Helical Steel Wire Structural Strand
 - 6. ASTM A615 Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
 - 7. ASTM A690 Standard Specification for High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments
 - 8. ASTM A722 Standard Specification for High-Strength Steel Bar for Prestressing Concrete
 - 9. ASTM C150 Specification for Portland Cement
 - 10. ASTM C33 Specification for Concrete Aggregates
 - 11. ASTM F432 Specification for Roof and Rock Bolts and Accessories
 - 12. ASTM F436 Specification for Hardened Steel Washers
- C. American Wood Preservers' Association (AWPA):
 - 1. AWPA C3 Specification for Below Grade Preservative Treatment for Wood

- D. State of California, Department of Transportation (Caltrans), Office of Structure Construction, "Trenching and Shoring" Manual.
- E. Post Tensioning Institute (PTI): Post-Tensioning Manual, Chapter 4, Recommendations for Prestressed Rock and Soil Anchors

1.05 DEFINITIONS

- A. Drainage Mat or Matting: A manufactured drainage material which is available in sheets or rolls and which may be used in excavation support systems to prevent buildup of hydrostatic pressure.
- B. Lagging: A temporary or permanent excavation support structure consisting of heavy timber boards, planking, sheathing, or reinforced precast concrete planks secured in place by steel H-piles.
- C. Proof Load: An applied load 25 percent greater than the design load, imposed by load test.
- D. Secant Wall: An excavation support system consisting of a series of drilled, spaced soldier piles and intersecting, unreinforced concrete drilled piers or drilled shafts arranged in an arched configuration, filled with a lean concrete-mix cement and sand grout.
- E. Sheet piling: A line of timber or planks, plain or tongue-and-grooved on sides, driven endwise into the ground to protect sub grade operations.
- F. Sheet Piling: Interlocking steel sheet piling installed vertically to hold back earth or retain soil and to keep water out of a foundation excavation. May be a temporary or permanent structure.
- G. Shores/Shoring: Props or posts of timber or other material in compression, used for temporary support of excavations.
- H. Slurry Wall: A reinforced concrete wall constructed by filling a trench with tremie concrete. Tremie concrete displaces the bentonite slurry already in the trench, forming a concrete barrier, when set, which retains the earth or soil on the exterior side of the slurry wall, and permits excavation and removal of the soil on the interior side of the wall.
- I. Soil Anchor: A pre-stressed frictional anchorage device, consisting of a high-strength steel tendon, fitted with a stressing anchor at one end and an anchor device, permitting force transfer to the soil, at the other end, installed in a prepared hole that is drilled or driven into the ground.
- J. Soil Mix Wall: A multiple-augered, cement-grout reinforced earth technique, incorporating steel H-beam reinforcement, whereby existing soils are mixed in place with cement grout, forming a row of overlapped soil cement columns, creating a reinforced earth wall excavation support system.

- K. Soil Nailing: A soil reinforcement technique whereby an in-situ retaining structure is constructed by making successive excavations using driven or grouted reinforcing bars (or nails) to support the soil. Soil nailing does not require pre-stressing. Soil nailing requires simultaneous application of shotcrete to retain the excavated wall facing.
- L. Soldier Piles: Vertical steel H-piles installed to take the side thrust of horizontal lagging. Also called soldier beams.
- M. Strut: A brace or supporting member which resists thrusts in the direction of its own length; may be vertical, diagonal, or horizontal.
- N. Tie-Backs: An excavation-face support obtained by grouted steel bars, wire strands, or tendons, with or without a dead-man, in combination with face-retaining or bearing steel plates, board timbers, or shotcrete reinforcement.
- O. Tremie Concrete: Concrete placed by means of tremie equipment, for depositing concrete under water and thereby displacing bentonite slurry in a slurry-wall trench or excavation.
- P. Waler: A horizontal beam used to brace or support vertical sheeting or sheet piling.

1.06 DESIGN CRITERIA

- A. Basic unit stresses for the working stress design of excavation support structures shall be taken from the following references:
 - 1. Structural Steel: Manual of Steel Construction, American Institute of Steel Construction (AISC).
 - 2. Reinforced Concrete: Building Code Requirements for Structural Concrete, American Concrete Institute, (ACI 318).
 - 3. Timber: California Building Code.
- B. Design excavation support systems to support earth pressures, utility loads, equipment, applicable traffic and construction loads, and other surcharge loads in a manner which will allow the safe and expeditious construction of permanent structures without movement or settlement of the ground and in a manner which will prevent settlement of and damage to, or movement of, adjacent buildings, structures, utilities, or other facilities during the various stages of construction. Include evaluation of the effects of dewatering and flooding of excavation.
- C. Design each component to support the maximum loads that may occur during various stages of construction. Include lateral pressure due to earthquake. For the purpose of this Section, the design load means the maximum load the support member will have to carry in actual practice, and the proof load means a specified test load greater than the design load. Shoring is required for excavations in the zone of influence. Zone of influence is defined here in Section 3.01. Seismic and wind loads shall be included in the shoring design. The soil and inertia lateral seismic design loads shall be determined by geotechnical engineer based on the specific site

seismicity. For temporary structures with an expected duration of less than five years, the site seismicity shall be based on a probabilistic ground motion with ten percent probability of exceedance in ten years and shall not be less than 0.1g. For temporary structures with an expected duration of over five years, the seismic loading for permanent retaining structures shall be used. For structures to be shored for 180 Days or less, wind loads and design shall be in accordance with ASCE/SEI 37. For structures to be shored for over 180 Days, wind loads and design shall be in accordance with applicable codes for permanent structures. Shoring shall be required to maintain at-rest soil condition and monitored for movement.

- D. Support of excavation structures shall be analyzed for all conditions which may occur during the various stages of construction. Among others, these conditions include: installation, relocation and removal of struts; flooding and dewatering of excavations; and concreting of excavation bottom. The loading conditions on opposite sides of a cut may not be equal. In this case, both sides shall be designed for and be compatible with the larger loading. The conditions to which the design applies shall be indicated on the Shop Drawings.
- E. Carry the bottom of support system to a depth below the main excavation as adequate to prevent lateral and vertical movement. Where additional excavation is carried below the main excavation, provide means to prevent movement of the main excavation supports.
- F. Design the excavation support system to allow the required free excavated space for workers, concrete formwork, wall waterproofing, and drainage systems.
- G. Design excavation support systems for staged installation and removal to conform to construction and backfill sequences as indicated. Leave excavation support systems in place, except as specified otherwise herein or in the Contract Specifications.
- H. Employ walers, struts, and tieback anchors for horizontal support as required for excavation faces to be retained by soldier piles and lagging, sheet piles, or by concrete slurry walls. Provide struts with intermediate vertical and horizontal supports as required to prevent buckling. Struts shall be preloaded by wedging or jacking to 50 percent of the design load.
- I. Provide diagonal bracing where needed for stability of the system. Use timber lagging, steel sheeting, or reinforced precast concrete sheeting or planking. Tiebacks and soil anchors will not be permitted to extend outside of the BART right-of-way property limits, unless the Contractor has obtained written (notarized) permission from adjacent property owners to use their properties for such purposes.
- J. Design piles or other vertical support members to be incorporated in a system employing tiebacks or soil anchors to have the capability of resisting vertical components of tieback loads without significant settlement during any stage of excavation and construction.
- K. Timber support systems, except lagging, shall be employed only for utilities and minor structures. Timber supporting members and lagging to be left in place shall be pressure-treated with wood preservative.

- L. Where lagging is employed, the Contractor shall design the lagging to safely support the indicated loads. Minimum thickness of lagging between soldier piles spaced up to 7 feet on center shall be 3 inches for excavations of depth up to 25 feet, and 4 inches for excavations of depth in excess of 25 feet.
- M. Soil-nailed walls may be used where soil conditions are appropriate. Shotcrete facing is required for all soil-nailed walls. Include vertical strips of drainage matting before shotcreting to assure proper drainage.
- N. Provisions shall be made to protect struts from excessive deformations and stress variations induced by temperature fluctuations.
- O. In reviewing submittals, the Engineer will use the criteria and loads for structures indicated on the Contract Drawings. The conditions to which the design applies shall be indicated on the Shop Drawings.

1.07 SUBMITTALS

- A. General: Refer to Section 01 33 00, Submittal Procedures, and Section 01 33 23, Shop Drawings, Product Data and Samples, for submittal requirements and procedures. Shop Drawings and supporting calculations for excavation support systems shall be submitted to the Engineer for review and approval.
- B. Pre-construction Surveys: Submit pre-construction surveys as specified in Article 1.08 A. herein.
- C. Movement Detection Procedures: Submit procedures for detection of movement as specified in Article 3.01 herein.
- D. Excavation Support Systems Program:
 - 1. Prepare and submit a written schedule and procedure, along with detailed drawings, of the proposed excavations and excavation support systems.
 - 2. Include installation procedures; method of concrete placement; excavation sequence; interface details; protection measures for existing structures and facilities; instrumentation and monitoring procedures to check performance, sequence, and method of removal; and contingency plans for excessive wall or foundation movements.
 - 3. The program shall take into account that excavations cannot extend beyond the BART right-of-way into adjacent properties above or below grade, unless otherwise indicated. Where tie-backs, soil anchors, soil nailing or similar support systems are required, the Contractor shall be solely responsible for securing permission from adjacent property owners to install such temporary and permanent systems. If the Contractor is unable to secure such permission, support systems shall be installed completely within the BART right-of-way.

- a. Any such permission from adjacent property owners shall be in writing, and the owner's signature, granting such permission, shall be witnessed and properly notarized. Certified copies of all such permissions shall be submitted to the Engineer for record purposes.
- E. Shop Drawings: Submit Shop Drawings and specifications for support systems, lagging, tie-back anchors, and internal bracing. Include the following:
 - 1. Specific description of field quality control measures.
 - 2. Details of interface with permanent structures.
 - 3. Detailed description of tie-back soil anchors, soil nailing, and wales, if used, and the proposed installation procedure, including method of grouting anchors, grout type, and mix proportions.
 - 4. Details of bracing struts and wales, if used, and the proposed installation procedures, including method and sequence of preloading.
 - 5. Details of required preloading systems, pre-stressing systems, load measuring facilities, systematic schedule of preloading and pre-stressing operations, and sequence of construction.
 - 6. Method and details for securing lagging in support system openings.
 - 7. Proposed method of providing for utility penetrations.
 - 8. Assembly and erection details of members and connections for the system.
- F. Calculations: Submit appropriate design calculations to support Shop Drawings. Include maximum theoretical deflections of supporting members. Include calculations indicating the expected magnitude of vertical and lateral movement.
- G. Professional Engineer's Certification: The excavation support systems program, Shop Drawings, calculations, and test reports shall be prepared, sealed, and signed by a professional civil or structural engineer currently registered in the State of California. The Contractor shall select an engineer with experience in the design and construction of excavations and excavation support systems and shall submit the selected engineer's resume demonstrating such experience.
 - 1. Where Caltrans approval for excavation support or shoring is required, submit check calculations and related documents prepared, signed, and sealed by an independent civil or structural engineer currently registered in the State of California. The check documents shall confirm the essential elements of the design and shall be prepared in accordance with the Caltrans Trenching and Shoring Manual.
- H. Calibration Charts: Submit certified calibration charts for each jack-gage unit used for preloading.

- I. Test Reports: Submit reports of performance tests and proof loading tests of soil anchors, certified by a professional civil or structural engineer currently registered in the State of California.

1.08 REGULATORY REQUIREMENTS

- A. Regulatory requirements that govern the work of this Section include the following governing codes:
 - 1. California Code of Regulations, Title 8, Chapter 4, Subchapter 4 — Construction Safety Orders.
 - 2. California Code of Regulations, Title 24, Part 2, California Building Code, Chapter 33 and Appendix Chapter 33, and Structural Chapters 18 and 18A.
 - a. Excavations, regardless of depth, shall comply fully with the requirements of Sections 3301.2, 3301.2a, and 3301.3 of the California Building Code.

1.09 SITE CONDITIONS

- A. Pre-construction Surveys: The Contractor shall submit to the Engineer, for review and approval, pre-construction surveys for existing structures and facilities located above or adjacent to the new construction and which may be affected by the work. These surveys shall include photographs, maps, plans, written descriptions, and surveyed foundation levels as necessary to fully document pre-construction conditions.
- B. Provision for Contingencies:
 - 1. Monitor performance of components of excavation support systems, both for vertical and horizontal movement, at regular intervals. Provide strut-monitoring devices, installed in accordance with the manufacturer's instructions, at locations indicated or required.
 - 2. Provide and secure approval for a contingency plan, or alternative procedures, to be implemented in the event of an unfavorable performance of the system.
 - 3. Have materials and equipment available to implement the approved contingency plan.
- C. Existing Utilities:
 - 1. Proceed with caution in areas of utility facilities and structures. Expose existing utilities by hand-excavation or by other methods acceptable to the utility owner'.
 - 2. If existing utility facilities and structures interfere with proposed method of excavation support, modify or relocate such facilities in accordance with the utility owner's recommendations.

- D. Loads: Lateral loads shall not be transferred to new concrete structures by removal of excavation support systems until the new structure has attained its 28-day compressive strength, or except as otherwise indicated.

PART 2 – PRODUCTS

2.01 EQUIPMENT AND FACILITIES

- A. The Contractor shall furnish all tools, equipment, devices, appurtenances, facilities, and services for the construction and removal of excavation support systems as indicated or required.

2.02 MATERIALS

- A. General: Materials for excavation support systems may be new or used, provided they are sound and free from strength-impairing defects.
- B. Soldier Piles/H-Piles: ASTM A690 or ASTM A36 shapes of sizes indicated on approved Shop Drawings. Provide soldier piles or H-piles of sizes required to contain lagging, sheeting, or planking as indicated.
- C. Steel Sheet Piling: ASTM A328, continuous interlocking type, of sizes indicated on approved Shop Drawings, with suitable handling holes.
- D. Timber: Structural grade lumber with a minimum fiber stress in bending of 1100 psi.
 - 1. Lagging: Heavy timber boards or planking of sizes indicated on approved Shop Drawings. Lagging boards or planking shall be secured and contained in place by H-piles (soldier piles), with boards inserted in the recesses between the H-flanges.
 - 2. Posts, Struts, and Walers: Heavy timber posts, beams, stringers, and planking, as required, of sizes indicated on Shop Drawings.
 - 3. Preservative Treatment: Wood members required to be left permanently in place shall be pressure-treated with preservative material in accordance with AWPA C3.
- E. Concrete: Refer to Section 03 11 00, Concrete Forming, Section 03 20 00, Concrete Reinforcing, Section 03 30 00, Cast-In-Place Concrete, and Section 03 05 15, Portland Cement Concrete, for requirements. Provide Class 4000 concrete with a minimum cement content of 6.5 sacks per cubic yard unless otherwise indicated. Lean concrete, where indicated, shall conform to requirements of Section 03 05 15, Portland Cement Concrete.
- F. Shotcrete: Refer to Section 03 37 13, Shotcrete, for requirements.

- G. Tremie Concrete for Slurry Walls: Class 4000 concrete with coarse aggregate of one-inch maximum size (ASTM C33 size No. 57). Slump at placement: 5 to 6 inches, plus or minus one inch.
- H. Bentonite Slurry: Natural Wyoming type granular bentonite, graded so that 90 percent will pass a 20 mesh sieve and less than 10 percent will pass a 200 mesh sieve, mixed with water. Bentonite slurry shall be a stable suspension of powdered bentonite with a minimum density of 65 pcf and a maximum density of 85 pcf.
- I. Tiebacks:
 - 1. Steel Bars or Rods: ASTM A615, Grade 60, threaded steel bars or bars conforming to requirements of ASTM A722 or ASTM F432, as applicable of sizes indicated on approved Shop Drawings. Provide complete with header or face plates conforming to ASTM A36 where required, nuts conforming to ASTM A563, and washers conforming to ASTM F436, as indicated or required.
 - 2. Wire Strands: Single-strand or multiple-strand galvanized steel wire conforming to ASTM A416 or ASTM A586, as appropriate.
 - 3. Grout: Pumpable concrete, with minimum compressive strength at 28 days of 4,000 psi. Concrete mix shall contain 6.5, 94-pound sacks of cement per cubic yard minimum. Aggregate size shall be commensurate with the space being filled. Comply with requirements of Section 03 05 15, Portland Cement Concrete, as applicable.

2.03 SOIL ANCHORS

- A. Product Standards: Comply with applicable requirements of PTI Post-Tensioning Manual, Chapter 4, Article 4.5, Soil Anchors. Provide soil anchors complete with stressing anchorage and bearing plates, sheathing and pre-stressing steel, grout and grout tube (if required), and the required drilling equipment.
- B. Bars: ASTM A722 deformed pre-stress threadbars, with a minimum ultimate tensile strength of 150 ksi.
- C. Wire Strand: ASTM A416, Grade 270, low relaxation, seven-wire stress-relieved strand, with ultimate tensile strength of 270 ksi.
- D. Anchorage Grout: Portland cement, aggregate, water, and a manufactured non-corrosive expansive admixture, of suitable aggregate size and consistency for pressure grouting. Grout shall develop a minimum compressive strength at 28 days of 4,000 psi. The Contractor may substitute a high-strength, non-shrink, nonmetallic cementitious grout conforming to applicable requirements of Section 03 61 11, Non-Shrink Grout.

2.04 SOIL NAILING

- A. Steel Bars: ASTM A615, Grade 60, threaded, deformed steel bars of sizes indicated on approved Shop Drawings. Provide complete with steel face plates, nuts, and washers as specified herein for tiebacks. Steel face plates shall engage the shotcrete reinforcement.
- B. Shotcrete: Comply with applicable requirements of Section 03 37 13, Shotcrete.
- C. Drainage Matting: Comply with applicable requirements of Section 33 46 00, Subdrainage, for the preformed permeable drainage liner.
- D. Concrete Reinforcement: Reinforcing steel bars (rebar) and welded wire fabric shall comply with applicable requirements of Section 03 20 00, Concrete Reinforcing.

2.05 SECANT WALL SYSTEM

- A. Structural Steel for Soldier Piles: ASTM A690/A690M H-piles or ASTM A36/A36M wide-flange I-beams or H-beams as applicable.
- B. Cement Grout: Two sacks of ASTM C150, Type I, Type II, or Type III cement per cubic yard of grout, combined with ASTM C33 fine aggregate, to provide a flowable filler mix.
- C. Steel Casings: Provide temporary drill casings where required to prevent caving of unstable soils.

2.06 SOIL MIX WALL SYSTEM

- A. Soldier Piles: As specified above in Article 2.05.A, as applicable.
- B. Materials and Equipment: Provide all materials and special equipment as required to perform the augering, mixing, and grout injection and to complete the soil-mix wall system.

PART 3 – EXECUTION**3.01 DETECTION OF MOVEMENT**

- A. For each existing structure and track or facility within a zone of influence extending upward from the bottom of the excavation on a slope of 2 horizontal to 1 vertical, install settlement detection devices on each footing, foundation, wall, or other feature to be monitored. Settlement detection devices shall be capable of being read to an accuracy of 0.005 foot.
- B. Take and record readings not less than once per week during performance of the work.

- C. Stop work; notify the Engineer, and take immediate remedial action if movement of the existing structure occurs during performance of the work. All construction activities shall be immediately halted when the settlement of any structure or facility reaches 0.3 inch, and shall not be resumed until after implementation of approved remedial measures. Consult Engineer for track monitoring requirements.
- D. Upon completion of the work, take weekly readings of the measurement points for a period of 4 weeks, or longer if movement persists, and report the results to the Engineer.
- E. The detection of movement shall be performed by a qualified licensed and surveyor or civil engineer.

3.02 INSTALLATION REQUIREMENTS

- A. Existing footings, foundations, pile caps, grade beams, retaining walls or pavement which may be affected by excavation operations shall be shored or underpinned adequately or otherwise protected against settlement and lateral movement without relying on any other existing structures for stability or support.
- B. Construct support systems in accordance with approved Shop Drawings and in a manner that will ensure that supported faces will be stabilized. Provide for additional soil pressure caused by adjacent surcharge loads.
- C. Welding and welder's qualifications shall conform with applicable requirements of Section 05 05 22, Metal Welding.
- D. No part of the excavation support systems that will remain permanently in place shall be placed or allowed to deflect within the limits of permanent structures.
- E. Piles and vertical members of excavation support systems shall be within 1.0 percent of plumb and within 2 inches of the plan location indicated on approved Shop Drawings.
- F. Install lagging members as indicated and in a manner which will prevent loss of soil. Wedge lagging members against undisturbed earth or place compacted fill or slurry fill into voids behind lagging.
- G. Do not use combustible waste or similar material for packing or soil retention in excavations.

3.03 INSTALLATION OF SOLDIER PILES AND LAGGING

- A. Provide pre-bored holes for soldier piles adequate to accommodate pile sections indicated. Extend holes to depth below level of adjacent sub grade as necessary to provide firm bearing. Piles may be driven below the bottom of the invert of the completed structure if soil conditions are favorable for the intended purpose.
- B. After a pile has been seated plumb in the pre-bored hole, encase it with lean concrete from the bearing tip to level of adjacent sub grade excavation.

- C. Provide timber lagging or reinforced precast concrete members, secured in place to soldier piles, contained in the recesses between the H-flanges. Install lagging horizontally with no gaps between boards or precast members.
- D. As installation progresses, backfill voids between excavation face and lagging with sand or soil rammed into place. Provide drainage matting or burlap where necessary to allow drainage of ground water without loss of soil or sand packing.
- E. If unstable material is encountered during excavation, take suitable measures to contain such material in place and to prevent soil displacement.

3.04 INSTALLATION OF SHEET PILING

- A. Drive sheet piles in plumb position, with each pile interlocked with adjoining pile for its entire length so as to form a continuous diaphragm throughout the length of each run of wall. Drive to depth indicated.
- B. Provide driving method so that interlocking members can be extracted, if required, without injury to adjacent fills.
- C. Do not drive piles within 100 feet of concrete less than seven days old.
- D. Methods of driving, cutting, and splicing shall conform with approved Shop Drawings and procedures.

3.05 CONSTRUCTION OF SLURRY WALLS

- A. Slurry Trench Equipment:
 - 1. Employ equipment capable of removing foreign material from the trench, including boulders. Arrange equipment to permit free vertical passage of slurry within the trench, and to prevent development of suction or pressure.
 - 2. Furnish trench inspection tools or devices adequate to assure that the trench has been excavated to dimensions indicated on approved Shop Drawings, and that settled cuttings and excavated material have been removed.
 - 3. Employ slurry mixing equipment capable of producing, with mechanical agitation, a stable suspension of bentonite and water. Transport bentonite slurry to trench panels by temporary pipelines or by other suitable methods.
 - 4. Furnish equipment to provide circulation and agitation of the slurry throughout the full depth of excavated panels. Do not agitate slurry pneumatically.
 - 5. Employ slurry reclaiming equipment which will remove detrimental quantities of excavated material from the slurry to assure use of clean slurry in trenches. Recirculate reclaimed slurry to trenches in a continuous operation.
 - 6. Monitor slurry and control its capability for retaining solid particles in suspension.

B. Construction:

1. Construct slurry trench walls by displacing bentonite slurry with tremie concrete.
2. Construct walls of reinforced concrete or plain concrete with embedded structural steel, or unreinforced plain concrete as indicated on approved Shop Drawings. Where soldier piles are used in construction of walls, such piles may be considered as reinforcement.
3. Provide sufficient embedment of walls below subgrade of adjacent excavation to prevent heave, loss of ground due to piping under the wall, or lateral movement of the wall.
4. Perform preparatory work to discover, protect, maintain, relocate, and restore utility facilities and structures near the slurry walls.
5. Employ construction methods that assure that slurry materials provided during trench excavation and placing of tremie concrete are contained and controlled to prevent leakage and spillage of slurry and excavated materials into basements, vaults, utilities, and other facilities.
6. Excavate slurry wall trenches in panels of widths and depths indicated on approved Shop Drawings, with a maximum panel length of 18 feet. Reduce panel length when excavating adjacent to facilities sensitive to settlement.
7. Maintain wall panels full of slurry to within the limits indicated on approved Shop Drawings during excavating operations and until tremie concrete placement is completed. Continue construction with two panel spaces between two slurry panels under active excavation.
8. Keep slurry circulated or agitated during drilling and excavating, and immediately before concrete placement. Maintain slurry requirements at all times, including non-working periods and stoppages. Provide continuous circulation or agitation, if necessary, to meet these requirements.
9. Place concrete by tremie pipe, either by gravity flow or by pumping. Equip tremie pipe with a bottom valve to prevent mixing of slurry with the concrete inside of tremie pipe.
10. Start placement of tremie concrete in excavated panels within 12 hours of completion of excavating the panels, and proceed continuously until completion of concrete placement.
11. Construct tight joints between adjacent concrete placements by properly excavating the trench and cleaning abutting face of hardened concrete, or surfaces of structural members if used.
12. Seal leaks encountered in walls as the excavation progresses, if such leaks permit penetration of fines and loss of soil.

13. Dispose of unsuitable excavated material and debris in accordance with the requirements of Section 31 11 00, Clearing and Grubbing.
14. Dispose of slurry waste offsite in accordance with applicable regulations of governing authorities.

3.06 SUPPORT SYSTEMS WITH BRACING AND TIEBACKS

- A. Requirements: Provide walers, struts, rakers, shores, and tie-backs as necessary to support excavation faces retained by posts, soldier piles, or concrete slurry walls.
- B. Internal Bracing:
 1. Provide walers where required, at each level of bracing. As excavation proceeds, place walers on open face of support system wall. Wedge, drypack, and otherwise provide tight bearing between walers and support system wall, with ample bearing areas to provide uniform transfer of loads.
 2. Provide struts with intermediate bracing as needed to enable struts to carry the design load without distortion or buckling.
 3. Provide diagonal bracing as needed for stability of the system.
 4. Include web stiffeners, plates, angles, or bracing as needed to prevent rotation, crippling, or buckling of connections and points of bearing between structural members. Allow for eccentricities caused by field fabrication and assembly.
 5. Install and maintain internal bracing support members in tight contact with each other and with the surface being supported.
 6. Design internal bracing support members for maximum loads which may occur during excavation and removal stages.
- C. Tie-Backs:
 1. Provide tie-back anchorage system as necessary to support structures and excavations. Install tie-back system in accordance with approved Shop Drawings.
 2. Tie-backs shall not extend beyond the BART right-of-way and easement properties, except as specified in Article 1.07.D.3. herein.
 3. Install manufactured tie-back or anchorage systems in accordance with the manufacturer's instructions.
 4. Stress installed tie-backs to proof loads indicated on approved Shop Drawings. Tie-backs which lose more than five percent of applied proof loads or deflect more than 6 inches shall be reinforced and strengthened to withstand applied proof loads.

5. Apply proof loads as herein specified, and provide means to measure each load application within an accuracy of plus or minus five percent.
6. After load-test approval, reduce tie-back proof load to the design load, and encase tie-back anchorage and bars or rods in grout, lean concrete, or compacted backfill, as indicated, maintaining the design load until tie-backs are fixed in place. Provide a method of fixation that will limit the load loss to not more than five percent of the design load in the transfer of loads from the jacks to the support system.

D. Proof Loading:

1. Perform proof loading of internal bracing members and tie-backs, including struts, shores, and similar members. Employ procedures that will produce uniform loading on bracing members and tie-backs without inducing eccentricities or overstressing and distortion.
2. Perform and accomplish proof loading by approved load testing or jacking procedures. Submit detailed Shop Drawings of proposed load testing and jacking procedures.
3. Apply proof loads as soon as possible after bracing and tie-backs are installed in accordance with methods, procedures, and sequences as indicated on approved Shop Drawings.
4. Coordinate excavation work with installation of bracing and tie-backs and with the application of proof loading. Provide steel shims and wedges, welded or bolted in place, to help maintain the proof-loading force on the bracing and tie-backs after release of load-testing pressures.

E. Creep Tests on Tie-Backs:

1. Load test tie-backs for creep at each level of support in the excavation, at the first installation on each side of the excavation, at horizontal intervals not exceeding 500 feet, and wherever a significant change occurs in the soil in which the tie-backs are anchored.
2. Perform a 24-hour load test on one out of each 100 tie-back anchors. Perform tests by applying the proof load and maintaining it constant for 24 hours.
3. Keep records of axial movement with incremental applications of the load, and the amount and time of load fall-off with no pumping of the jack or axial movement during the 24-hour period that the proof load on the anchor is maintained.
4. Redesign the tie-back system to attain specified limits if, during the 24-hour period, the axial deformation of the tie-back system exceeds 0.20 inch, or the decrease in jack pressure without pumping is more than five percent after correcting for temperature changes.

3.07 SOIL ANCHORS

- A. Install soil anchors where necessary to support structures to be underpinned and those that will be affected by underpinning and restoration work. Other existing structures shall not be used to add stability or support to the temporary supports.
- B. Installation and Testing Standards: Soil anchors shall be installed and tested in accordance with applicable requirements of PTI Post-Tensioning Manual, Chapter 4, Article 4.5, Soil Anchors.
- C. Installation:
 - 1. Angle tolerances shall be within one degree of those indicated on approved Shop Drawings.
 - 2. Deviation from planned orientation shall be no more than 2 inches in 10 feet.
 - 3. Drilling of anchor holes shall be by a proven system that utilizes a hollow stem auger or other approved method as appropriate for the soil conditions.
 - 4. Clean or redrill any hole that caves, sloughs, or otherwise does not provide suitable anchorage.
 - 5. Use spacers or sheathing to ensure that anchor tendons do not contact wall of drill hole. Maintain at least 2 inches of grout space around each tendon.
 - 6. Do not extend adjustment screws on cross braces or centerhole jacks used for loading soil anchors beyond manufacturer's recommendations or two-thirds of threaded length, whichever is more restrictive.
 - 7. Each jack used to stress tendons shall be equipped with a pressure gage for determining the jacking load applied to the tendon. Pressure gages shall have an accurate reading dial at least 4 inches in diameter or a clearly readable digital display.
 - 8. The tensioning process shall be conducted so that the tension being applied and the elongation of the pre-stressing steel may be measured at all times. A record shall be kept of gage pressures, elongations, and anchorage seating values and shall be submitted for record as specified in Section 01 78 39, Project Record Documents.
 - 9. Grout shall be injected at the lowest part of the anchor. Grout may be placed through the stem of the auger, through grout hoses, tubes, or pipes. Non-rigid hoses shall be attached to the lower end of the anchor with a break-away attachment that permits the hose to be removed as grout is placed. Pump pressure shall be maintained as grout hose or tube is removed.
 - 10. Locate soil anchors so as not to damage or destroy active utility facilities. Any deviation shall obligate the Contractor to repair, replace, or otherwise restore such damage to the satisfaction of the utility owner.

- D. Tests: Test each soil anchor after being grouted for its entire bond length and after grout has attained a minimum compressive strength of 3000 psi. One anchor or one percent of anchors in any wall section, whichever is greater, shall be designated as a performance test anchor. Performance test anchors shall be installed and tested prior to placement of production anchors. All production anchors shall be proof tested.

3.08 SOIL NAILING

A. Installation of Nails:

1. Soil nails shall be installed at locations and to the depths indicated on approved Shop Drawings, employing a drilling and grouting method appropriate for the soil in which they are to be installed.
2. Dewatering, as specified in Section 31 23 19, Dewatering, shall be performed in advance of soil nailing work to facilitate soil nailing in dry soil conditions.
3. Provide nail length and nail diameter necessary to develop the load capacity and to satisfy testing acceptance criteria for the required design load, but not less than the lengths and diameters indicated on approved Shop Drawings.
4. An initial cut in the soil shall be made to a depth governed by the ability of the soil to stand unsupported, but not greater than the required vertical spacing of the soil nails.
5. Drill holes for soil nails at locations indicated on approved Shop Drawings, with the actual location within 6 inches of the indicated location. The nail angle shall be located within plus or minus 3 degrees of that indicated on approved Shop Drawings. Adjust dimensions to suit field conditions.
6. Core drilling, rotary drilling, percussion drilling, auger drilling, or driven casing may be employed for soil nailing. Choose drilling methods that will maintain open drill holes and which do not promote mining and loosening of the soil at the perimeter of the drill hole. Where groundwater or local seepage causes holes to cave in, revise the drilling procedure to provide continuous support of the hole.

B. Grouting:

1. Provide grouting equipment capable of continuous mixing, producing a grout of proper consistency free of lumps. Nails shall be placed in each drilled hole within 15 minutes of the grout injection.
2. Place centralizers at 10-foot intervals in the total length with the last centralizer 1 foot from the end of each nail, and ensure that not less than 1-1/2 inches of grout cover is achieved around and along the nail. Centralizers may be omitted when pressure-grouting through hollow stem augers with a stiff grout mixture of 8 inches or less slump.

3. Inject or pump grout at the lowest point of the drill hole. Pump grout through grout tubes, casing, hollow-stem augers, or drill rods, such that the hole is filled free of air voids, with the grout filling the hole progressively from bottom to top. Inject or pump grout until the hole is completely filled and clean grout is seen to be running from the top of the hole.
4. Subsequent excavation shall not proceed until the grout has attained a minimum compressive strength of 1,000 psi.

C. Shotcreting:

1. As soon as practicable after soil nails are installed, cover the excavated wall face with a layer of reinforced shotcrete.
2. Shotcrete shall conform to the requirements of Section 03 37 13, Shotcrete. Provide straight, plane surface with cutting screed.
3. Just before shotcreting, provide drainage matting over the wall face to relieve hydrostatic pressure conditions. Drainage shall be collected at the wall base and properly directed to drainage outlets.
4. Also, just before shotcreting, tighten each nail nut one-half turn past snug tight. Pre-stressing is not required.
5. Wet set or provide other suitable method, such as dry pack, to provide even bearing against the shotcrete face, between the plate and the shotcrete.

D. Tests:

1. Provide a complete proof loading program. At least one nail per 100 linear feet of wall at each excavation level shall be tested. In addition, designated performance or sacrificial nails shall be tested to failure.
2. Soil nails shall not be tested until the anchorage grout has attained a minimum compressive strength of 3,000 psi.
3. Apply an alignment load (plus or minus 10 percent of the design load) and record the nail position.
4. Apply and increase the soil nail load in progressive steps of 25, 50, and 75 percent of the test load, and record the nail movement at each step. Maintain each incremental load for a minimum of one minute.
5. Bring the soil nail load up to 100 percent (test load) and, after movement has stopped, maintain the load for five minutes. The time period may need to be adjusted, based on the soil nail performance.
6. The following are acceptable nail movements:
 - a. Total nail deformation shall be limited to 1 inch.

- b. Nail movement during the five-minute 100 percent test load shall be limited to one-tenth of an inch.
- 7. Reduce soil nail load to zero and tighten nut.
- 8. Based on these test results, adjust soil nail hole diameter, nail lengths, and spacings as required.

3.09 SECANT WALLS

- A. Design and construct secant walls as indicated or required. Drill beam holes and intersecting pier holes in sequence selected. Provide arched configuration of piers between beams. Provide temporary casings if necessary to prevent cave-ins of unstable soils. Set and align H-beams where they occur. Place toe concrete in beam holes to within 6 inches of the design sub grade. Fill balance of beam holes and intersecting pier holes with a cement grout filter mix. Concrete and cement grout may be end-dumped, provided drill holes remain stable during placement.

3.10 SOIL MIX WALLS

- A. Design and construct soil-mix walls as indicated or required. Construct walls in the ground without excavating and replacing the existing soils. Existing soils shall be mixed in place with cement grout, produced by multiple-shaft augering equipment, forming a row of overlapped soil-cement columns or piers that make the wall. Install regularly spaced H-piles for wall reinforcement as indicated on approved Shop Drawings. Carry toe of wall and H-piles at least 3 feet below design sub grade.

3.11 REMOVAL OF EXCAVATION SUPPORT SYSTEMS

- A. Excavation support systems shall be removed wholly, unless otherwise approved by the Engineer or stated in this specification section. Perform such removal in a manner that will not disturb or damage adjacent buildings, structures, construction, or utilities. Fill voids immediately with lean concrete or with approved backfill compacted to the relative compaction for the location as specified in Section 31 00 00, Earthwork.
- B. Excavation support systems shall be left in place until the concrete walls and structures to receive the transferred loading from the removed support system have reached 100 percent of the specified compressive strength at 28 days. Demonstrate with strength test results that the concrete has reached the specified strength before load transfer from the support system to the concrete structure may be performed.
- C. Secant walls and soil-mix walls shall be left in place.
- D. Remove from the site all elements of excavation support systems to 6 feet minimum depth below the level of surfaces to be constructed or restored.
- E. Repair damage to properties resulting from removal work.

3.12 RESTORATION

- A. Restore existing structures to conditions equivalent to those existing prior to the start of work, including repair of settlement-related damage.

END OF SECTION 31 50 00